NEW LABORATORY EQUIPMENT

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For many years the American Psychological Association has arranged for the display of apparatus at its annual meetings. Scattered articles on apparatus have appeared also from time to time in our psychological journals. Both of these methods of exposition reveal in its material aspects the growth of empirical psychology, but the author is strongly of the belief that there is not yet enough mutual coöperation in the way of improving our empirical resources in general and our laboratory equipment in particular. Committees have been at work on our laboratory methods, our laboratory experiments, and our class-room management; but, apart from special pieces of apparatus planned for particular researches, we have not yet an adequate exchange for ideas concerning laboratory equipment. The annual exhibition has not induced enough laboratories to participate and not all new pieces from our laboratories can be safely and conveniently transported. However useful these annual displays are—and the author does not mean to disparage them in any way,—accurate descriptions of apparatus in our journals, accompanied by illustrations whenever possible, are sure to appeal to a larger group and will leave a more permanent record in our archives. Demonstrations, in our opinion, are invaluable, but they ought to be accompanied by accurate specifications. By writing out in detail a series of descriptions of new equipment designed and constructed in our laboratory during the last few years, the author attempts to express his agreement with Seashore when he writes:

> The Cornell Laboratory has set a good example in reporting detailed specifications for the following five pieces of apparatus. It is very desirable that the various laboratories should adopt the plan of describing fairly permanent pieces of apparatus apart from the report of the research.[1]

TUNING-FORK OF VARIABLE INTENSITY.

The principle upon which the construction of this apparatus rests is that of wave-interference and virtual cancellation at points lying in planes which make angles of 45 degrees with

[1] Seashore, C. E. Apparatus, *Psychol. Bull.*, 10, 1913, 32.

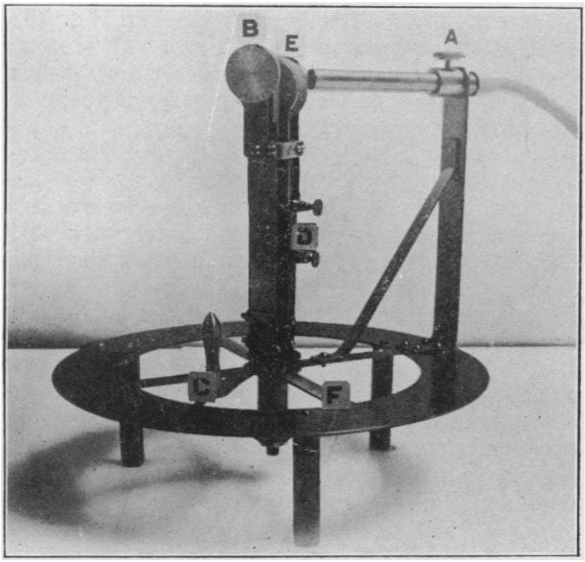

FIG. 1.—Tuning-Fork of Variable Intensity.

a plane passing midway between the tines of a tuning-fork and parallel to their sides. If the tines of a tuning-fork are therefore rotated opposite a conducting tube which is held stationary in a position perpendicular to the axis of rotation, a point of virtual cancellation of wave disturbance, together with phases of partial cancellation on either side, will pass the tube four times in a complete revolution.[2]

The fork is electromagnetically driven by means of a primary fork operated in series with it through the binding posts (D) and electromagnet (E), and removed to another room to eliminate extraneous noises. It is accurately tuned to a pitch of 100 vd. and the amplitude of its vibrations can be gauged to 1/1000 in. by means of a micrometer-screw (B) whose head, 1¼ in. in diameter, carries a scale indicating twenty-fifths of a revolution and whose stem, with 40 threads to the inch, permits the adjustment of its tip until contact is made between it and the side of the tine. A brass tube, 5 in.

[2] A similar form of apparatus has been suggested by F. M. Urban: Ein Apparat zur Erzeugung schwacher Schallreize, *Arch. f. d. gesam. Psychol.*, 27, 1913, 232-234. The principle of interference is described in detail in Barton, E. H. A text-book on sound, 1908, 374-377; Helmholtz, H. L. F. On the sensations of tone (trans. Ellis), 3rd Eng. ed., 1895, 161; Windelband, A. Handbuch der Physik, Vol. 2 (Akustik), 1909, 602.

long and ½ in. in diameter, and a large rubber tube connected to it, conduct the sound to the ear. The brass tube is held in position by means of an angle-brace, is adjusted by rotating the knurled screw (A), and terminates on the side nearest the fork in a vertical slit ⅜ in. long and ⅛ in. wide.

The fork is mounted on a spindle to which a handle and indicator (C) are attached. On the circular base the degrees of rotation are engraved, starting with the zero-point at the position in which the tines of the fork are both in a straight line with the tube and extending 90 degrees on either side. Most of the construction is of 1/16 in. brass. The base is 10 in. in diameter; the brass tube stands 6¾ in. above the base; and the three legs are 2¾ in. long and are covered with rubber tubing which extends over their ends to diminish conduction of sound through the base.

The apparatus readily lends itself to experiments in the field of auditory acuity (*cf.* note 1), and if the intensity is accurately calculated from physical equations, it ought to be of service in investigations of the *DL* as well as the *RL* for intensity.

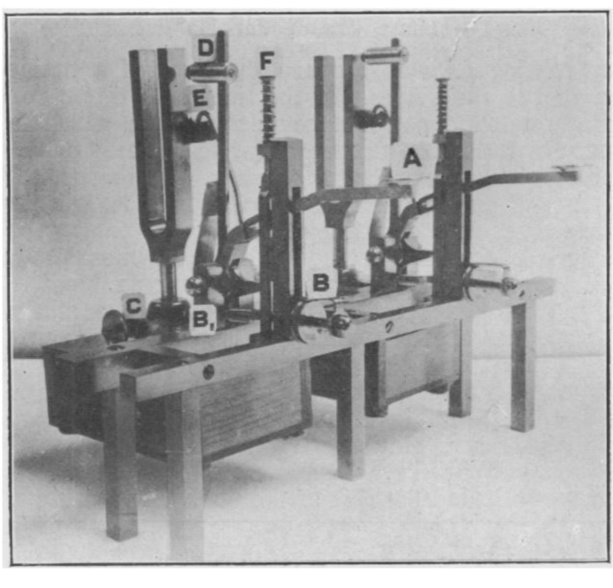

FIG. 2.—Automatic Tuning-Fork Hammers.

Since this apparatus is simply a double form of an instrument described in a previous article, detailed specifications

will be omitted.[3] The type of apparatus illustrated has the advantage of being more easily adapted to experimental investigations in which two successive stimuli, differing in pitch or in intensity, are required at short intervals. The essential features are: a key-rod (A) which depresses a slide (F) and momentarily releases the damper (E) while the fork is being struck. The hammer-piece (D) is engaged by means of a pawl by the slide in its downward movement and against the action of a tension-spring (seen to the right of B), whose tension can be regulated by a knurled nut (B). Near the point of extreme depression the hammer-piece is suddenly and automatically released. It strikes the tine of the fork with a force dependent upon the tension of the spring attached to its lower end. A clamp (C) is provided for holding the fork in place and is adjustable to fork-stems of varying thicknesses. The instrument serves very well for demonstrational purposes in large lecture-rooms and for investigational studies in the laboratory.

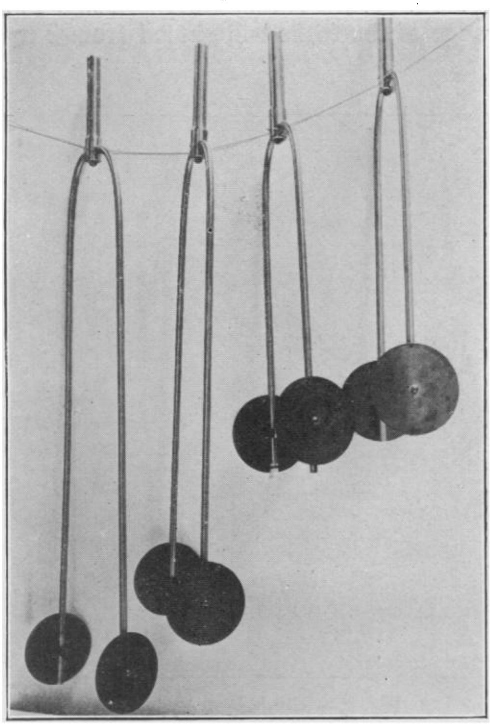

FIG. 3.—Adjustable Wire Forks.

[3] Bentley, M., Boring, E. G., and Ruckmich, C. A. New apparatus for acoustical experiments, *Am. J. of Psychol.*, 23, 1912, 515-516.

ADJUSTABLE WIRE FORKS.

A set of four wire forks has been made for the purpose of investigating the stimulus-limen for pitch, the relation of noise to tone, and analogous problems in acoustics. The four forks are uniform in construction; dimensions differ only in the length of tines and in the amount of their separation at the extreme ends. The tines of the two smallest forks measure 17 in. in length and are separated 5½ in. at the end; the tines of the next larger fork are 24 in. long and are separated 6 in. at the end; and the largest fork has tines 29 in. long and separated 6½ in. at the end. The tines of all of the forks are slightly divergent. They are made of ⅜ in. tool-steel with a handle of ¾ in. steel cut to a length of 5¾ in. A heavy pin and screw fasten the tines to the handle. Hard fibre discs, 3/16 in. thick and 3⅞ in. in diameter, mounted on the tines by means of adjustable brass thumb-screws, serve as riders and at the same time amplify the intensity of the vibratory disturbance. When permanently adjusted and calibrated, the total range of the forks will extend from 8 to 40 vd.

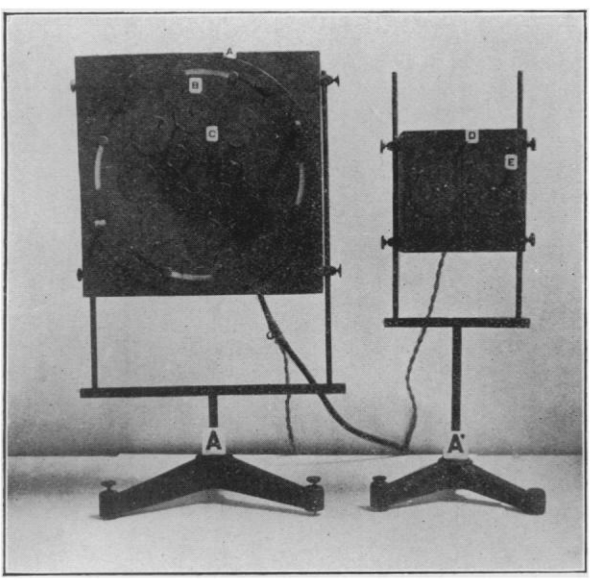

FIG. 4.—Blind-Spot Apparatus.

In connection with a doctorate thesis it became necessary to provide a reliable control of eye-movement. One of the

methods used in this research was the well-known procedure involving successive determinations of the position of the blind-spot. There was no standard piece of apparatus available by means of which this work could be quickly and accurately done. The requirements of the method were satisfactorily met by instruments which were constructed in the departmental machine-shop.[4] The apparatus on the left (A) is used to map out the blind-spot; the one on the right (A′) furnishes the fixation-point. The experiment is performed under dark-adaptation. The principal feature of the larger apparatus is a sheet-iron box 12 in. square and 6 in. deep, mounted by a set of four thumb-screws on a bracket and tripod 22 in. high. The box contains a 16 c. p. electric incandescent lamp fixed in the center of the door which forms the back. The front of the box carries a circular plate 12 in. in diameter. This plate is attached to the box by four broad rivets moving in slots which are cut into the plate in the form of an arc of 45 degrees (one of these arcs is to be seen just above B). The plate is rotated through this arc by means of two projecting handles. Two circular rows of eight discs are mounted on the plate, those in the outer row (B) measuring 2 in. in diameter with centers 3 3/32 in. from the center of the plate, those in the inner row (C) measuring 1⅛ in. in diameter with centers 1½ in. away from the center of the plate. The discs are provided with projecting flaps by means of which they may be rotated. A series of five holes is drilled in each of the larger discs, and a series of three holes in each of the smaller discs. These holes are located on concentric circles with 3/16 in. difference in radius and at points 22½ degrees of rotation apart. The holes are 3/32 in. in diameter. Behind the discs, drilled into the plate along each of four partial diameters that are spaced at angles of 45 degrees, there is a series of 32 still smaller holes corresponding exactly to the successive positions of the holes in the discs under which they lie. The light within the box is allowed to penetrate the holes in the plate only when the holes in the discs are made to correspond with them. Since each disc may be rotated 360 degrees, it successively uncovers double the number of holes that it contains. Furthermore, since the large circular plate may be rotated 45 degrees and since

[4] While the suggestions of members of the department are in large measure responsible for the original design of pieces of apparatus described in this article, Mr. Clayton F. Harding, the departmental machinist, has added other suggestions or has materially improved the original design in the course of construction. The department will undertake to supply any of the pieces described at prices which can be had on application.

the exact position of the plate may be determined from an engraved scale (barely seen to the right of small A), all points, located in a circular field of about 8 in. in diameter and at distances of 3/16 in. units from the center of the plate, can be investigated. The fixation-box (A′) in a like manner permits the adjustment of the fixation-point in the vertical and in the horizontal direction. The vertical direction is controlled by a sliding rod (D) and the horizontal direction by two discs 2½ in. in diameter. The holes are of the same diameter as those in the other box, are 3/16 in. apart, and number twelve in each direction in addition to the common central point. The box is also adjustable in the vertical plane by means of four set-screws on the side of the box; it is cubical in shape; and it measures 6 in. on each side. A 16 c. p. incandescent lamp is fastened inside the box. Both pieces of apparatus are finished in flat black on the outside and are enameled in white on the inside. They are provided with electric cord attachments for a 110 v. circuit; resistance may be introduced to avoid halos or pronounced after-images. Two set-screws are inserted in each tripod in order to give the boxes an absolutely vertical position.

The apparatus is set up a meter and a half from the observer's eye. His head is kept steady in a head-rest. After the fixation has been determined, the blind-spot apparatus is adjusted so that points are found that are just within the blind area. The distance between the blind-spot apparatus and the fixation-point apparatus is arranged to suit the requirements of different observers. When the apparatus is set for any one individual, the points thus determined naturally mark the areal extent of that observer's blind-spot at the distance mentioned. Whenever any one or more of these points become visible, other conditions[5] being equal, eye-movement is indicated.

DISC CUTTER.

An improved form of cutter, used in connection with experiments in color-mixture, in peripheral vision, and in any field which requires paper-discs of uniform sizes, has been built in the laboratory and has given satisfactory service. While it was built primarily for cutting paper-discs, with the exercise of care, thin cardboard may also be cut.

The base (F) consists of ½ in. cast-iron covered with 1/16

[5] These conditions include absolute fixation of the head, accurate and immediate report of the visibility of the spots of light, and the special factors which must be taken into account generally in investigations of the visual sensations.

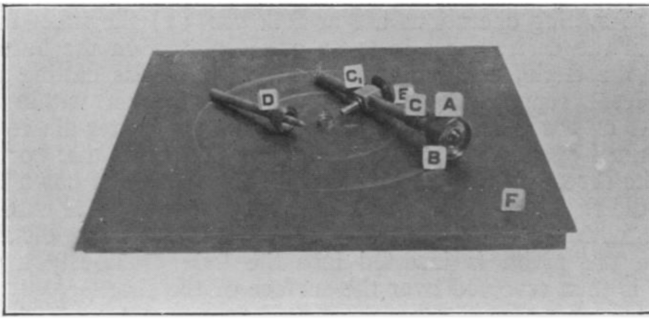

FIG. 5.—Disc Cutter.

in. soft brass which is fastened to the iron by means of six brass machine-screws. The base measures one foot square. The cutting-wheel (B) is made of tempered steel, one inch in diameter, and is protected by a knurled brass hood (A), ¾ in. wide. On the side which faces the base it is flattened to permit the projection of the blade on the surface of the paper. The hood is permanently screwed to the stem of the cutter to prevent rotation and consequent tearing of the paper. The pivot (E) is made of steel, 9/16 in. square, and contains on its lower surface a steel pin, ⅝ in. long and 3/16 in. in diameter, which fits into a steel die, mounted in the center of the base, measuring ½ in. in outside diameter, and projecting 3/16 in. above the surface of the base. On the upper surface of the pivot, a knurled brass thumb-screw is provided for adjusting the distance between the pivot and the cutting-wheel. This thumb-screw is about an inch in diameter and carries a pin which fits into a key-way on the upper surface of the cutting-stem. This also insures against the rotation of the hood (A). For purposes of rapid and accurate adjustment, two stops (C and C_1) are provided. These consist of brass collars that fit the cutting-stem. They are fastened with small knurled thumb-screws which project into the key-way on the stem. The two positions at which these stops are maintained correspond to the two sizes of discs commonly used in our laboratory, *viz.,* 11 cm. and 20 cm. in diameter respectively. The stem is graduated in centimeters to facilitate the process of adjustment. A center-punch (D) completes the outfit. The pointed end of this device fits into the steel die in the center of the base and the brass cup which is mounted on the stem is made just large enough to pass snugly around the outside of the die.

The cutting operations are as follows: (1) the sheet from which the desired disc is to be cut is placed on the base so that the circle, engraved thereon from previous cutting and therefore representing the desired size, is just within the limits of the sheet; (2) the position of the center-die is determined by a slight pressure with the thumb on that portion of the sheet; (3) the centre-punch is brought point down into the die to cut the hole and is then removed; (4) the cutting-tool, with its wheel adjusted at the proper cutting distance from the pivot, is inserted into the hole previously made, and is then revolved over the surface of the sheet.

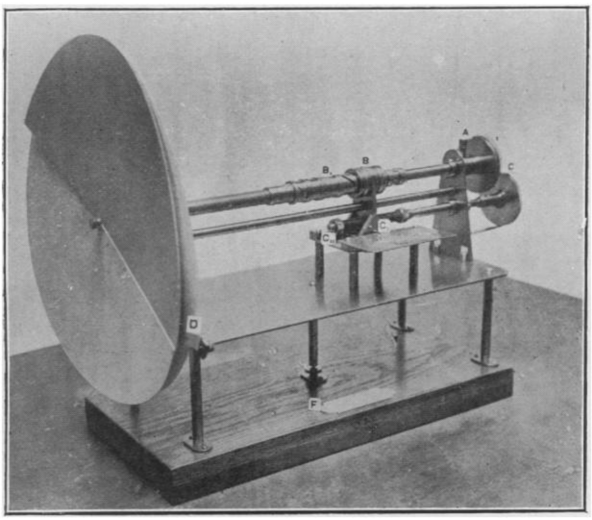

FIG. 6.—Variable Color-mixer.

This is a modification and enlargement of the Musil[6] color-mixer which, in turn, is an improved form of the Marbe mixer. With the larger construction naturally new problems of detail had to be solved, so while the principle is not entirely new, several of the important features are original. Reference to the diagrams which illustrate the Musil pattern will indicate the major changes.

The colored papers which represent the color-components to be mixed are mounted on cardboard to prevent ruffling

[6] Spindler and Hoyer, Psychological apparatus, Catalog No. 21, 1908, pp. 52-54.

and tearing. The diameter of the discs which the apparatus will carry is 16 in. The discs are slit in the usual way. On the flap nearest the machine a cardboard lip is attached and is inserted through a slit in the heavy backing behind the color-discs. An ordinary pin holds this securely in place. The backing and the attached color-disc are mounted on the inner axle of the machine. The other color-disc is attached by means of a clamp (D) to a balanced arm which projects from the outer axle or casing. Except when changes are made in the composition of the mixture, both inner and outer axles are rotated together with the pulley and shaft (A). This pulley is of brass, 3¼ in. in diameter; the shaft with its attachments is 23 in. in length. The steel inner axle is ⅝ in. in diameter; the outer brass casing is ¾ in. in diameter. Oil-cups and bushings are provided at both ends and at the end nearest the color-discs where the wear is greater, ball-bearings are located. To vary the mixture the large brass dial (C) is turned. The amount of change can be read on the face of the dial in units of a degree or fraction thereof. For convenience and accuracy a pointer indicates the exact position of the dial. As the dial is rotated, the steel stem, to which it is attached and which carries 11 threads to the inch, moves the carriage (behind C_1) along tracks on the platform (on either side of C_{11}). The carriage-arm is flanked by two ball-bearing collars (B) which are fastened to the casing containing the spiral key-way. The key-way makes one complete turn in 3½ in. of its length and is reënforced by three brass bands which encircle it. To prevent this casing from turning in relation to the inner axle, it carries a pin which travels in a straight key-way cut into the inner steel axle (between A and B). The outer axle with its casing attached to the variable color-disc is equipped with a lozenge-shaped pin which follows the spiral key-way. Since the casing which carries the spiral key-way cannot rotate with respect to the inner axle and its color-disc, the outer axle with its variable color-disc and casing must be the one to rotate in relation to the inner axle when adjustment is being made, because the pin which guides its movement is compelled to follow the spiral path as the casing which contains this spiral key-way is moved back and forth by the carriage-arm. By means of a pointer attached to the carriage, the platform (C_1) indicates samples of the colors which are being mixed and the respective amounts of the mixture in units of five degrees. The whole apparatus stands about a foot high on an oak base, 10 in. wide and 20 in. long, and is supported by five legs, the center one (F) being adjustable

to prevent the sagging of the large brass base-plate. The apparatus has been tested out with a 1/6 H.P. Emerson electric motor at a speed sufficiently rapid to prevent flicker and has been found serviceable for demonstrational purposes.[7]

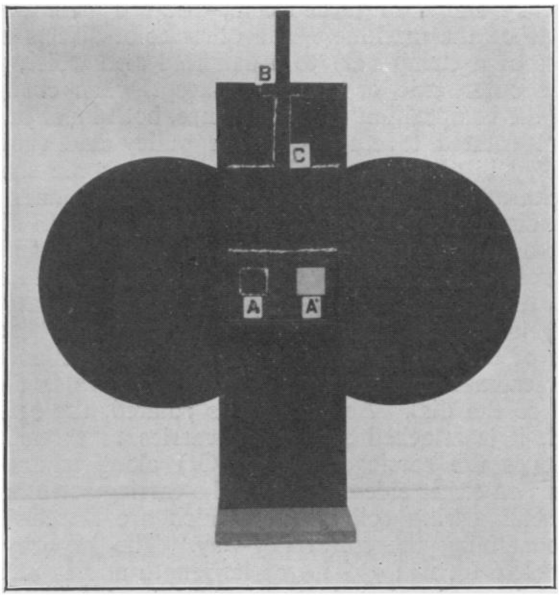

FIG. 7.—Apparatus for Paired Exposures.
(Front View)

This apparatus was built for the purpose of presenting a series of twelve colors according to the procedure of paired comparisons in the standardised form of the method of impression. It is used both for laboratory exercises and for demonstrational work.

On the side facing the observer (fig. 7) nothing is seen except the upright wooden frame 30 in. high and 9 in. wide at the base with two partial circles extending 12 in. on either side of the upright frame. When used in laboratory exercises, the experimenter raises the slide (fig. 7, B) and with it the attached shutter (fig. 7, just below C) by means of the handle (fig. 8, under B). If he finds it convenient, the

[7] The type of motor used automatically assumes the load only after its full speed has been attained.

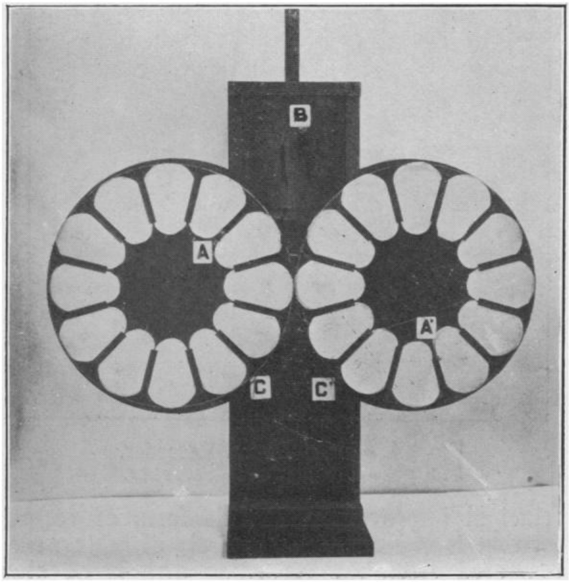

FIG. 8.—Apparatus for Paired Exposures.
(Rear View)

experimenter may set the pivoted end of the slide into a metal socket provided for the purpose of keeping the shutter open. The colored papers are then visible through the two apertures (fig. 7, A and A′), which are 2 in. square and 2 in. apart. The colors are changed by rotating the sheet-iron wheels (fig. 8, A and A′), which carry the papers in thin metal runways. A backing of cardboard serves to keep the papers flat and displays the number of the color in the series. Holes, 2¾ in. in diameter, are cut into the wheels opposite the apertures seen from the front (fig. 7, A and A′). To make certain that the colors are in their correct positions, notches are cut in the circumferences of the wheels to correspond to each successive exposure. A spring trigger (fig. 8, barely seen at C and C′) momentarily prevents further rotation. The apparatus is finished in dead-black. It is our experience that by means of this apparatus the papers are presented in a much more systematic fashion and are kept in better condition than in the process of ordinary manipulation.

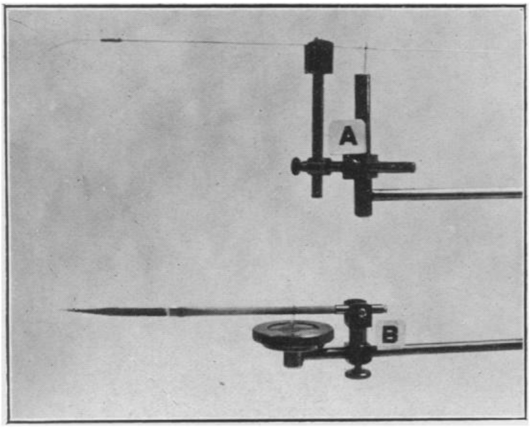

FIG. 9A.—Metal Piston Recorder.
FIG. 9B.—Demountable Tambour.

The principal improvement in this form of recorder lies in the fact that it is constructed entirely of metal; the pivots are of tempered steel, the recording arm is of aluminum, and the rest is of brass. Hence it has an advantage over the Lombard-Pillsbury form in that the irregularities of plaster and glass are avoided.[8] The cylinder, measuring 3 in. in length and 1/4 in. in inside diameter, is carefully bored and ground out and accurately fits a small brass plate, less than 1/32 in. in thickness, which forms the piston-head. Into this plate is soldered a very light brass wire, 1 1/2 in. long, and hooked at the end which enters the hole in the aluminum recording arm. This arm, 8 in. in length, is accurately balanced and carries on its farther end a short hog's bristle. The entire moving parts weigh 1.542 grams, or about four times the weight of the corresponding parts in the Lombard-Pillsbury recorder. Two small set-screws are provided to hold the pivots in position; the pivots are also adjustable.

While we have not yet tested the inertia and comparative accuracy of the recorder, several score trials have resulted in records that compare favorably with those made by the earlier models. The apparatus requires much less attention. For one thing, the need of constant lubrication and the consequent removal of accumulated oil is avoided. It is likely that further improvement will be made along the line of reducing the weight of the moving parts.

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[8] Lombard, W. P., and Pillsbury, W. B. *Am. J. of Physiol,* 3, 1900, 186-200. Modifications of this form of recorder are described in Shepard, J. F., The circulation and sleep, 1914, p. 7.

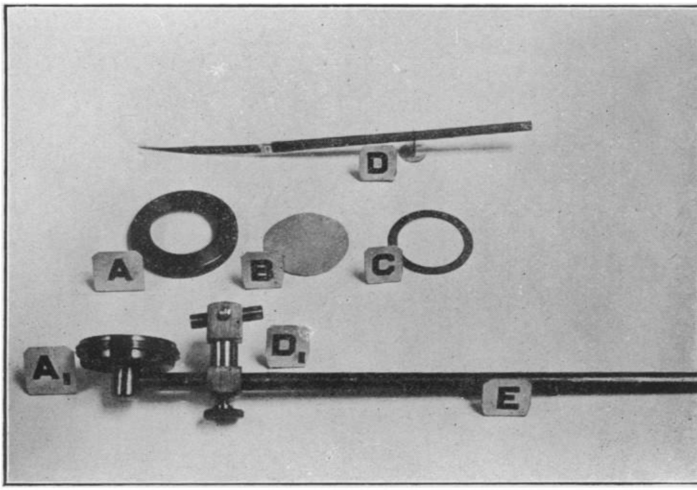

Fig. 11.—Demountable Tambour.

The chief advantage in this form of Marey tambour lies in the fact that the rubber dam is very readily renewed. The tambour is shown in both the assembled (fig. 9B) and in the unassembled state (fig. 11). The main parts are: (1) the writing-arm (D), 6½ in. long, made of an ordinary soda-straw, with a celluloid point attached by means of an aluminum band and with a bent celluloid bridge which rests on the rubber dam; (2) a knurled brass cap (A) which, after the rubber dam (B) and the washer (C) have been put into position, fits over the capsule (A_1) and holds the dam tightly over the capsule with an area of about an inch in diameter left free to vibrate; and (3) the stem (E) made of brass tubing 9½ in. long and ¼ in. in diameter, opening into the capsule and carrying the pivot (D_1) into which the writing-arm is inserted (as in fig. 9B). A half-inch knurled set-screw attaches the pivot-block to the stem and allows adjustment for writing-points of various lengths. Since the bridge is also adjustable, the same writing-point may be given greater or less length and consequent excursion on the drum.

ADJUSTABLE STANDARD.

A new pattern of adjustable standard has been constructed in the laboratory. The main adjustments are made by means of a thumb-screw (B), one inch in diameter, and a knurled nut (A), 1½ in. in diameter. The thumb-screw has a long

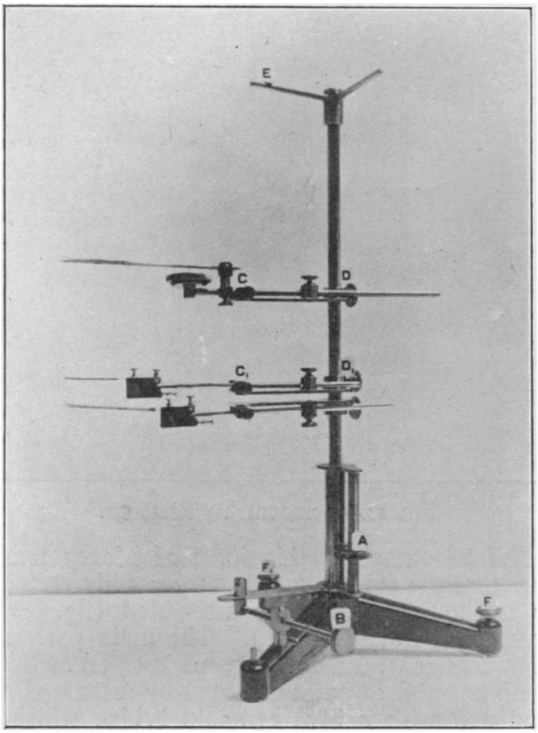

FIG. 10.—Adjustable Standard.

threaded stem which passes through a horizontal pivot-block inserted into one of the legs of the large cast-iron tripod. The stem has a total length of 5½ in. and a diameter of ¼ in., and carries twenty threads to the inch. On the opposite end from the head this stem is fitted into an arm projecting 5 in. from the center of the main shaft and fastened thereto. The shaft rotates on its vertical axis in obedience to the adjustments of the thumb-screw (B), and consists essentially of two parts: the upper, made of half-inch solid brass rod and telescoping into the lower in response to adjustments made by means of the knurled nut (A). The latter moves vertically on a stem, 4½ in. long and ½ in. in diameter, carrying 12 threads to the inch. In so doing it operates a ¼ in. pin with a roller bearing which travels in a groove deeply cut into the side of the nut. This pin is rigidly fastened into the telescoped portion of the upper shaft. A key-way is cut

into the side of the lower shaft facing the nut to allow the pin to move with the nut. The lower shaft is made of ¾ in. brass. The threaded stem is held in place by two horizontal projections 1½ in. from the center of the main shaft. As the nut is rotated, it moves up or down the stem and carries with it the upper portion of the standard to which the markers are attached.

Three arms are provided with the standard, two of them so arranged that they may be moved as closely together as the instruments carried will permit. The arms are constructed of ⅛ in. brass, as are all similar parts in the apparatus; they vary from 2¼ to ⅞ in. in width, and are 4⅝ in. long; and they are fastened to the upper shaft of the standard by ⅞ in. set-screws which travel in a key-way cut in the shaft (D and D_1). A half-inch collar is attached to the arm to give sufficient body to the thread for the set-screws. A block is provided for attaching the markers or writing devices. This is one-half inch high and ¾ in. in diameter, and has a ⅜ in. hole drilled horizontally through it. The required device is inserted into this hole, is fastened by means of the set-screw inserted from the top, and is permitted side-play by virtue of the slight rotation of the block on the arm. At the outer end of the arm (C and C_1) is a set-screw, 1½ in. in length, which carries a loose concave plate at the end of its stem. Operating against this plate is a similar one backed by a compression spring on a sliding rod, 1½ in. long. The writing device is inserted between these plates and can be adjusted toward or away from the kymograph-drum by turning the set-screw.

At the top of the shaft, two additional legs are attached so that the standard may also be used in the horizontal position. These legs are 4¼ in. long, ¼ in. in diameter, and are attached to a movable sleeve at an angle of about 60 degrees with one another. The standard is made almost entirely of brass, stands at an average height of 24 in., and can be adjusted in the vertical position by two set-screws mounted in the tripod (F and F_1).

WALL-CHARTS

A series of twenty-five charts, appropriate for use in the lecture-room and in the laboratory, has been prepared under the direction of the department. The charts were made by means of a compressed air-brush in the hands of the University Artist.[9] About one-half of them are tinted in colors;

[9] Requests for further information concerning these charts may be addressed to the Department of Psychology, University of Illinois, or to the artist, Mr. Charles W. Redwood, Forestry Bldg., Cornell University.

the rest are in black and white. The material used was water-color on heavy 'elephant paper' with cloth backing, 42 in. in width and from three to five feet in length. They were prepared ready for hanging with a strip of molding on each end.

Appended is a list of these charts; they are numbered in Roman notation. The Arabic numbers refer to the separate figures on the chart. There is a brief description and a citation of the source from which the chart was copied in each instance.

I. Organ of Audition.
  1. Semicircular canals in cochlea.
     From a stereopticon slide: photographic reproduction of a plaster model.
  2. Modified diagrammatic transection of right ear.
     After Czermak.
  3. Diagrammatic transection of a whorl of the cochlea.
     Foster, M. A text-book of physiology, 1891, vol. 4, fig. 177, p. 203.

II. Organ of Corti.
  1. General transection of the organ of Corti in the cochlea of a new-born pig.
     Shambaugh, G. E. *Arch. of Otol.*, 37, 1908, plate xiv, fig. 2, opp. p. 457.
  2. Similar transection showing bloodvessel under basilar membrane.
     Ibid., fig. 4.
  3. Similar transection to show the attachment of the membrana tectoria to hair-cells.
     Shambaugh, G. E. *Zeits. f. Ohrenhlk.*, 62, 1910, Taf. x, Abb. 2 (reversed), opp. p. 235.
  4. Transection similar to 3, to show attachment to outer hair-cells.
     Ibid., Abb. 5.

III. Analyses of complex Sound-waves.
  1. Graphic analysis of irregular, periodic, longitudinal vibrations into simple, regular, periodic, sinusoid vibrations.
     Wundt, W. Grundzüge der physiologischen Psychologie, 6th ed., 1910, vol. 2, fig. 171, p. 70.
  2. Graphic analysis of complex sound-wave into waves corresponding to a simple tone with an additional simple tone of double vibration-rate and of less intensity.
     Ibid., fig. 172(A), p. 72.
  3. Graphic analysis of complex sound-wave into waves corresponding to a simple tone with an additional simple tone of triple vibration-rate and of less intensity.
     Ibid., fig. 172(B), p. 72.

IV. Graphic representation of Vocal Sounds, showing irregular wave-structure.
  1. German vowel ā at c (= 128 vd.)
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  2. German vowel ō at c (= 128 vd.)
     Ibid., fig. 245(2), p. 396, after L. Hermann.

3. German vowel ü at c (= 128 vd.)
   Ibid., fig. 245(3), p. 396, after L. Hermann.
4. German vowel ē at c (= 128 vd.)
   Ibid., fig. 245(4), p. 396, after L. Hermann.
5. German vowel ī at g (= 192 vd.)
   Ibid., fig. 245(5), p. 396, after L. Hermann.
6. German pronunciation of 'ibba' at g (= 192 vd.)
   Ibid., fig. 246(7), p. 399, after L. Hermann.
7. German pronunciation of 'ikki' at e (= 160 vd.)
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V. Difference Tones.
   Schema of the primary difference tones with reference to the interval of the generating tones within the octave.
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VI. Circle of Complementary Colors.
   Hering's theoretical schema of the four primary colors and their resultant mixtures.
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VII. The Retina and Visual Theory.
1. Section of the retina.
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2. Graphic representation of the Hering components of color-vision as distributed over the visual spectrum.
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VIII. The alleged migration of Retinal Pigments.
1. Distribution of pigment-bodies during light-stimulation.
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2. Distribution of pigment-bodies before light-stimulation.
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IX. Miscellaneous Organs of Sense.
1. Olfactory receptor-organ in left nasal cavity.
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2. Olfactory receptor-cells.
   Ibid., p. 113.
3. Longitudinal and transverse section of a Meissner corpuscle in cutaneous tissue of the hand (cutaneous pressure).
   Ibid., p. 117.
4. Gustatory organs in papilla foliata.
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5. Gustatory organs in gustatory pore and taste-bud.
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6. End-bulb of Krause in cutaneous tissue (cold).
   Ibid., p. 117.
7. Pacinian corpuscle (subcutaneous or muscular pressure).
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8. Nerve-ending of Ruffini (warmth).
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9. Spindle of Golgi in tendon (tendinous strain).
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X. General view of demonstrational Rhythm-hammer (Cornell pattern).
Illustrating device for demonstrating temporal perceptions.
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XI. Cathedral Perspective.
Shows architectural curve in pillar to produce illusory exaggeration of height as viewed from the floor.
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XII. Dioptrics of the Stereoscope.
A dioptric diagram in colors illustrating the principle of the Brewster stereoscope.
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XIII. Synaesthesia: chromaesthesia.
Illustrations representing vowel, consonant, number, and word associations with colors.
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XIV. Synaesthesia: number-forms.
Illustrating the association of numerical series with diagrams.
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XV. The Expressive Method as applied to Emotion.
Fig. 1-3. Sthenic type of emotion expressed by curves representing breathing (above) and blood-volume, pulse-rate, and Traube-Hering waves (below).
1. Transition from pleasurable thought of successful work to unpleasurable thought of fatigue at 'a'.
Wundt, W. *Op. cit.,* 5th ed., 1903, vol. 3, p. 228.
2-3. A continuous curve representing strong anger induced by memory of heated argument. At first pulse is depressed (unpleasantness). Depression increases with continued emotion. Breathing is strengthened, shortened, and irregular.
Ibid., p. 229.
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XVI. Plan of Reaction Experiment.
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Wundt, W. *Op. cit.,* 6th ed., 1911, vol. 3, fig. 368, p. 366.

XVII. The Human Brain.
1. Adult type of fissuration, female, 29 yr., dorsal aspect, rich in gyres.
Retzius, G. Das Menschenhirn, 1896, vol. 2, plate 54, fig. 2.
2. Adult type of fissuration, male, 37 yr., dorsal aspect, poor in gyres, but unusual in type.
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3. Ventral aspect, showing cerebellum, male, 48 yr.
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4. Lateral aspect of left hemisphere, showing left aspect, male, 36 yr.
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5. Median section of cerebrum, showing median aspect of left hemisphere, male, 50 yr.
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XVIII. The Earthworm.

1. General view.
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2. Anterior segments.
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3. Sagittal section through anterior half.
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4. Central nervous system.
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Stereographic representation of the circulatory, digestive, and nervous systems in the middle segments (in color).
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XX. The Nervous System of the Earthworm.

1. Longitudinal section showing peripheral nervous system: cord and setae.
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2. Free nerve-endings in epidermis.
   After Smirnow.
3. Transection of cord showing neuronic connections.
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XXI. Sense-organs of the Earthworm.

1-2. Visual cells.
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3-6. Sense-organs in epidermis (chemical).
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XXII. Discrimination-box (University of Illinois model).

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1-3. Showing side, top, and general views, respectively.

XXIII. The Animal Maze (University of Illinois standardisation).

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XXV. The Salivary Reaction of the Dog (Pavlov's method).

Diagrammatic representation of the disposition of apparatus in connection with the expressive method as applied to the dog.
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